

Nuclear Energy and Proliferation: Problems, Observations, and Proposals

Taylor Burke

Federal Energy and Natural Resource Policy Seminar

Professor Langenkamp

December 3, 2004

I. Introduction

An aging nuclear reactor sits in Kinshasa, Congo. It was developed in the 1950s, as part of the American effort to win over popular appeal during the Cold War. Like all contemporary nuclear reactors in use, it is powered by materials that could, by remote possibility, be converted into a nuclear weapon. During some of the more difficult times in Congo's recent history, this reactor has sat unmonitored by local and international authorities; as the Bush administration looked for reasons to start a war with Iraq, this reactor was occasionally mentioned as a source of material for Saddam Hussein's nuclear weapon.¹ The problems associated with reactors like this have motivated contemporary foreign policy, and the implications of this policy (or lack thereof), are the subject matter of this paper.

The evolution of the nuclear technology has presented policy challenges to the United States, both domestically and abroad, in dealing with the problems of nuclear technology. Clearly, there are advantages to nuclear energy. It is relatively inexpensive for the amount of energy produced, meaning it can be used in relatively fossil fuel poor nations. It does not emit carcinogenic air pollution or carbon dioxide, making it an important component for any nation coming to terms with air pollution. There are obvious drawbacks to the technology. The waste generated by the nuclear fuel cycle is extremely dangerous and must be kept away from humans. Nuclear plants, with a remote capability for accident and remote possibility of a terrorist attack, require a great deal of security and bureaucratic oversight, thus making their use very expensive. There is also

¹ Douglas Pasternak & Eleni E. Dimmler, *A Home-Grown Nuclear Threat*, U.S. NEWS & WORLD REPORT Sept. 23, 2002, at 40.

the relationship between civilian and military applications of nuclear technology, posing a number of modern challenges to policymakers.

This paper examines that relationship between military applications and civilian uses of that technology, focusing on the methods taken by the United States to address this relationship. In order to understand the policies taken by the US, it is first necessary to analyze the history of the technology, the aspects of nuclear technology that enable security threats, the history of the US response to those threats, the current US policy on the issue, and finally, how that policy could be improved. This paper's overarching argument is that, because nuclear energy is a necessary component of an international energy strategy that will address the world's increasing energy demand, the US should promote nuclear technology, but only if it is willing to address the risk of proliferation related to this technology. This analysis concludes by examining three questions. 1) Should the United States promote the use of nuclear energy? 2) What measures can be taken to ameliorate the proliferation risks posed by nuclear energy? 3) Is the present division of labor appropriate within the federal government appropriate to address the myriad of issues created by the unique nature of nuclear technology?

In order to address those issues, it is necessary to examine the history of the US response to nuclear energy, the technology that enables nuclear energy, and the current response to nuclear proliferation.

II. History in United States: The Between of Military and Civilian Uses of Nuclear Technology

The nuclear energy industry was the result of the efforts of US military scientists during the 1930s and 1940s. During this period, the US explored military applications of

nuclear energy, focusing on how energy could be developed from the splitting of uranium atoms. The impact of this new area of science would affect all life in the world. In order to understand the current regulatory framework of nuclear energy, it is first necessary to understand the origins of the US policy response towards this technology.

A. Domestic Law and Policy

Nuclear energy literally began with a big bang: the attacks on Hiroshima and Nagasaki were the result of the US efforts during World War II. The technology and science that developed these weapons is, and will always be, related to the energy resource that followed it. After World War II, Congress passed the Atomic Energy Act of 1946² in order to address the profound implications of this new technology on America, both militarily and economically. While unsure of the long term implications of the technology, Congress was concerned with shaping the direction of the industry, “subject at all times to the paramount objective of assuring the common defense and security, the development and utilization of atomic energy shall, so far as practicable, be directed toward improving the public welfare, increasing the standard of living, strengthening free competition in private enterprise, and promoting world peace.”³ President Eisenhower followed suit in the 1950s with the Atoms for Peace Program which encouraged peaceful use of nuclear technology and served the political aspirations of the US during the Cold War. From the beginning of the nuclear era, the federal government has been concerned with the implications of this technology for security and foreign policy goals. As a result of this concern, the federal government has sought to shape the technology through a variety of legal and bureaucratic devices.

² Law of 1946, Ch. 724, 60 Stat. 755.

³ *Id.* at §1(a).

1. Atomic Energy Act.

Among the notable aspects of the Atomic Energy Act of 1946 (AEA) was the decision by Congress to make the nuclear industry a government monopoly, allowing for private groups to invest, subject to a great deal of federal oversight.⁴ The AEA's purpose is to regulate the various materials involved in the nuclear process. Under the current form of the law, the DOE has oversight of source materials⁵, special nuclear materials⁶, and byproducts.⁷

Congress found two primary motivations. First, there was the need for atonement after the attacks on Hiroshima and Nagasaki, which served as an impetus for developing peaceful applications of nuclear energy.⁸ Second, and very much ironically, there was a need to pursue the technology for purposes of the Cold War.⁹ There was a relationship, from the beginning, between developments in military and civilian applications of nuclear technology. For example, the light water reactor, a model frequently used in American nuclear power plants, was developed by the navy for use on submarines.

⁴ *Id.* at §7.

⁵ Source material is uranium, thorium, or any other material deemed by the NRC to be deemed source material and ores containing those materials. 42 U.S.C. § 2091 (2000).

⁶ "Special nuclear material" refers to plutonium, enriched uranium (isotope 233 or isotope 235). 42 U.S.C. § 2151 (2000).

⁷ This refers to any radioactive material made radioactive by exposure to radiation or other nuclear material. 42 U.S.C. § 2073 (2000).

⁸ Diane Carter Maleson, *Legal Response to Nuclear Power*, 55 SO. CAL. L. REV. 597, 598-600 (1982)

⁹ See Adam Tanner, *Nuclear power at a standstill; Power from 103 reactors provides 20 percent of U.S. electricity. Few people clamor publicly, though, for more nuclear energy, despite high oil prices*, PHILADELPHIA INQUIRER, Oct. 10, 2004, at A25, available at 2004 WL 94427478.

The act initially created the Atomic Energy Commission (AEC), which was responsible for licensing and energy development functions. The Energy Reorganization Act of 1974 split these functions into the licensing and energy development functions,¹⁰ creating the Nuclear Regulatory Commission (NRC) and the Energy Research and Development Administration (ERDA, the organization which eventually became the DOE). The NRC is charged, by Congress, with the health and safety aspects of the industry.

While safety is traditionally a state function, the original AEA was silent on the matter. In 1957, the law was amended to allow nominal state involvement in the regulation of byproducts, source materials, and small quantities of special nuclear materials.¹¹ States and the NRC sign agreements related to these regulations, after a finding by the NRC that the state's radiation control program is congruent with federal intentions.¹² States are also responsible for regulating nuclear energy with regard to their energy production as part of a utility system.

B. Price Anderson Insurance

Another important step in the process of creating a commercial nuclear industry was the Price Anderson¹³ “umbrella” for nuclear power operators. Given the almost unfathomable cost of a nuclear accident in the context of the American legal system, Congress realized that the fledgling nuclear industry at the time, which operated on the similar margins to other utility producers, would be unable to pay the cost of insurance.

¹⁰ 42 U.S.C. § 5801, et al (2000).

¹¹ 42 U.S.C. § 2021 (2000).

¹² *Id.*

¹³ 42 U.S.C. 2210(c) (2000).

Over the past five decades, Congress has developed a tiered system, in which nuclear producers share the insurance cost for accidents to a certain amount and Congress agrees to pay the rest in the event of a catastrophic accident.

C. Nuclear Energy in the courts

The legal system has had a limited response with the challenges of nuclear energy, interpreting the Atomic Energy Act and the Price Anderson provisions. In *Northern States Power Co. v. Minnesota*,¹⁴ the Eighth Circuit Court of Appeals ruled that the federal government preempted the state authority to regulate nuclear power plant operation and construction, allowing the AEC's authority to regulate release from nuclear plants. Another notable case, *In re TMI Litigation Cases Consol. II*, discusses the history of federal regulation of nuclear energy in depth, illustrating the method used to appropriate responsibility over nuclear energy, such as the Price Anderson system.

The overwhelming theme from the courts theme with regard to nuclear energy, however, has been one of deference.¹⁵ One commentator, Diane Carter Maleson, has noted that American courts are often very conservative with regard to emerging technologies and social concerns, comparing the deference of the courts with regard to nuclear energy to the slow response of the courts to address the problems created by

¹⁴ *Northern States Power Co. v. Minnesota*, 447 F.2d 1143, 114749 (8th Cir. 1971)

¹⁵ There are a few notable exceptions. See *Int'l Union of Elec., Radio and Mach. Workers, AFL-CIO v. U.S.*, 280 F.2d 645 (1960) (overturning an AEC approval of a breeder reactor project because it did not meet the safety standards in the Atomic Energy Act). On appeal, the US Supreme Court overturned the district court's decision, again deferring to the AEC's authority. *Power Reactor Dev. Co. v. Int'l Union of Elec., Radio and Mach. Workers, AFL-CIO*, 367 U.S. 396 (1961). See also *Porter County Chapter of the Izaak Walton League of America, Inc. v. AEC*, 515 F.3d 513 (7th Cir. 1975) (holding that AEC grant of permit for plant violated its own citing regulations). The circuit court was reversed. *N.Indiana Pub. Serv. Co. v. Porter County Chapter of the Izaak Walton League of America, Inc.*, 423 U.S. 12 (1975).

industrialization in the 1800s.¹⁶ Moreover, Carter notes that this deference is inspired by judicial trust in the technocratic regime, which she views as a policy choice in of itself: by deferring to administrative judgment, Carter argues that the court has changed nuclear energy from an “option” to a “mandate.”¹⁷

D. Analysis: Lessons of the Bureaucracy

These cases are particularly notable because they illustrate a unique aspect of the American nuclear system vis-à-vis that of other nations, namely the impact of the bureaucratic system of checks and balances that regulate all aspects of American nuclear technology. There are lessons to be learned regarding this system for comparative purposes. In the United States, there is a comprehensive system of checks and balances to ensure the appropriate divide between the goals and needs of industry and of the government. The federal government defines interests – security, safety, and an energy supply – and the appropriate entities – the military, the various civilian government entities at the state and federal level, the entrepreneurs – act in accord with that policy.

One of the major problems that shapes US nuclear policy is that this sort of system does not exist in every nation around the world. In one way or another, a few of the emerging nuclear states lack the sort of technocratic structure to divide those responsibilities. In some instances, those shortcomings create potential security risks for the United States, like the problem in Congo, and these sorts of problems are the focus of this analysis. The next step is discussing how the technology creates those risks.

III. The Nuclear Energy Process and Military Applications

¹⁶ Diane Carter Maleson, *Legal Response to Nuclear Power*, 55 So. CAL. L. REV. 597, 605 (1982).

¹⁷ *Id.* At 639-640.

Nuclear energy utilizes a relatively simple atomic reaction to generate steam which creates energy. There are several different technologies that have been developed to utilize this science and they each warrant specific explanation. These technologies can be used through a variety of means to develop nuclear weapons.

A. How does Nuclear energy work?

1. Generally

The short answer to the question of how a nuclear reactor works is that it releases energy from uranium and plutonium, which in turn is used to create heat that in turn heats water, which finally generates steam. A nuclear reaction creates the heat that leads to the electricity. There are several different ways to achieve this reaction, but there seems to be one fundamental model of how to achieve it.

Uranium has very unstable nuclei, some of which are continually breaking up or disintegrating. When the neutrons within uranium atoms collide with the nuclei of other uranium atoms, two or three neutrons will be released and the reaction will generate energy – this is the “fissioning process.” Isotopes of uranium, U-235 and U-238, have different properties from standard uranium. U-235 can more easily capture a neutron, fission, and release energy than a reaction, compared to U-238. However, U-238 is important because it can be used to form the element plutonium, through the absorption of neutrons. Nuclei of plutonium fission in a similar manner to uranium and are frequently used in commercial nuclear reactors. About forty percent of commercial electricity comes from plutonium.¹⁸

¹⁸ MAX W. CARBON, NUCLEAR POWER: VILLAIN OR VICTIM? 9 (1997). [Hereinafter Carbon.]

Generally, nuclear reactor has four parts: uranium or a combination of uranium and plutonium, water, devices that control the rate of fission, and a radiation shield.¹⁹ Uranium is usually shaped into small rods – normally referred to as fuel rods – to improve efficiency. Fuel rods are normally one-half inch in diameter and several feet in length.

2. Nuclear Fuel

Those who follow the news frequently hear nuclear-related terminology. It is worth briefly touching on the types of nuclear fuel used in reactors. The most important ingredient for a nuclear reaction is uranium: a relatively rare element.²⁰ In order to utilize uranium for many civilian and military applications, uranium must be enriched. Yellow Cake is processed uranium concentrate, containing seventy to ninety percent uranium oxide content. It is crushed, or compressed, uranium that is used in the enrichment process.²¹

Enriched uranium has a higher U-235 content through a process called isotope separation: several different methods, such as centrifugation and gas diffusion,²² have been developed to bring the U-235 content in fuel rods from three percent to five percent

¹⁹ Carbon, *supra* note 18, at 11

²⁰ See World Uranium Resources (RAR), available at <http://www.antenna.nl/wise/uranium/img/uresw.gif> (last updated 1/1/2001) (showing locations of uranium worldwide).

²¹ See BBC News, available at http://news.bbc.co.uk/2/hi/in_depth/world/2003/nuclear_fuel_cycle/conversion/default.stm (last updated Oct. 7, 2004) (explaining the yellow cake process and the uranium enrichment process).

²² Gas diffusion is the most frequently used technique in American nuclear reactors. The history of these processes is important to the history of the industry as a whole. A substantial amount of the Manhattan Project was dedicated to researching such processes. See Richard L. GARWIN & GEORGES CHARPAK, MEGAWATTS AND MEGATONS: A TURNING POINT FOR THE NUCLEAR AGE? 49-50 (2001). [Hereinafter Garwin and Charpak.] See also BBC News, Nuclear Fuel Cycle, available at http://news.bbc.co.uk/1/hi/in_depth/world/2003/nuclear_fuel_cycle/enrichment/default.stm (last updated Oct. 7, 2004) (illustrating the nuclear fuel cycle in some detail).

(up from the natural content of seventy one hundredths of a percent).²³ This content allows the fuel rods in a reactor to be placed closer together, allowing for more fission to occur.²⁴

Plutonium does not occur (in useful amounts) anywhere in nature, at least anywhere that has been discovered yet. Plutonium, a fundamental ingredient in nuclear weapons,²⁵ is obtained through a number of processes, two of which warrant specific attention. Plutonium is a byproduct in all civilian reactors at the moment, although military reactors are developed to create plutonium more efficiently – much of the plutonium created in civilian reactors is difficult to utilize for any re-use. Reprocessing plants, such as Breeder reactors, create plutonium that can be re-used as fuel within the reactor.

Mixed Oxide Fuel (MOX) accounts for between two percent and one third of the nuclear fuel used today.²⁶ It is derived from re-processed plutonium and is generally very costly to make. A discussion of MOX will be important in the discussion of Cooperative Threat Reduction below.

²³ Garwin and Charpak, *supra* note 22, at 48.

²⁴ *Id.* at 46-47.

²⁵ For a nuclear weapon to work, an explosive chain reaction must take place. By enabling more neutrons to react, the material reacts and generates more and more neutrons to react in a microsecond. In a nuclear reactor, the energy process is designed to maintain a chain reaction by regulating the system of fissioning so that only one neutron reacts at a time in the fission (control rods absorb the excess neutrons). Garwin and Charpak, *supra* note 22, at 34-35.

²⁶ Estimates over the amount used tend to vary, depending on who is writing the analysis. One estimate places it as 2%, but growing slowly. World Nuclear Ass'n, *Mixed Oxide Fuel (MOX)*, available at <http://www.world-nuclear.org/info/inf29.htm> (last updated July 2003).

Finally, thorium, another naturally occurring element, has been used in some nuclear reactors as an alternative to uranium based fuels.²⁷ There are some advocates who believe it can be developed into fuel that could not be used for nuclear weapons.

B. Reactor Types

A number of processes have been developed to utilize the reactions of uranium. Each has advantages and disadvantages.

1. Natural Uranium Reactors

Rather than use a uranium isotope, these reactors use the natural form of uranium.²⁸ This operation requires heavy-water moderator at atmospheric pressure: it is designed to limit the energy within fast fission neutrons, allowing the small proportion of uranium-235 nuclei within the material to be fissioned.²⁹ These reactors do not need the thick steel pressure vessels within other reactors. The advantage of these reactors is that they do not need the processing that comes with other reactors. The disadvantage is that they are not as efficient as the more advanced reactors, because they do not use refined uranium.

2. Water Reactors

In a light water reactor, water enters the reactor and then becomes steam as it passes through the reactor. These fuel rods are inserted into a reactor in a chamber filled with water. Water slows the pace of the neutrons because they lose energy as the uranium

²⁷ Thorium, which when used in a reactor core becomes U-233, was tested during the Manhattan Project, but has been disfavored because U-235 was viewed as a better fuel source. Seth Grae, *The Nuclear Non-Proliferation Treaty's Obligation to Transfer Peaceful Nuclear Technology: One Proposal of a Technology*, 19 *FORDHAM INT'L L.J.* 1985, 1993 (1996). Thorium is three times as abundant as uranium. WIKIPEDIA, *Thorium*, available at <http://en.wikipedia.org/wiki/Thorium> (last updated Nov. 27, 2004).

²⁸ There is one such reactor that has occurred naturally in Gabon, given a high concentration of water and uranium in the area.

²⁹ Garwin and Charpak, *supra* note 22, at 81.

neutrons react to the hydrogen in the water.³⁰ The water is pumped away from the uranium rods to carry the heat out of the chamber and to generate the steam that in turn generates electricity.³¹ Control rods, normally made of boron, regulate the rate of fission, use the element boron to absorb excess neutrons within the reactor. The steam created from the system spins a turbine and energy is created. Similarly, in a pressurized water reactor, leaves the reactor, and is then passed through the tubes in a heat exchanger; heat from that water makes its way from the system and boils another, separate, supply of water.³²

One benefit of the system is that it can safely create energy much more efficiently than natural uranium reactors. One of the benefits of nuclear energy which has not been specifically mentioned is the relatively low cost of uranium, given the relative amount of energy one can generate from the material. With this benefit comes a major long term problem: the limitation of these types of reactors is that there is a limited amount of uranium in the world. Indeed, some estimates posit that the supply of “easy-to-reach” material, given current demands, will only last another century.³³ Other drawbacks are common to most reactor types: highly dangerous nuclear waste and the (remote) possibility that the waste material is reprocessed into a weapon.

3. Liquid Metal Reactors

A more modern development in nuclear technology attempts to address the limitation of supply. Liquid metal reactors (“LMRs”), also called Breeder reactors,

³⁰ Carbon, *supra* note 18, at 12.

³¹ *Id.*

³² Carbon, *supra* note 18, at 13.

³³ *Id.* at 79.

consume less U-235 than plutonium generated, producing a net increase in fissionable material.

A reader with a basic knowledge of physics might be troubled by this concept, given the Second Law of Thermodynamics: "in all energy exchanges, if no energy enters or leaves the system, the potential energy of the state will always be less than that of the initial state."³⁴ The simple answer to this challenge is that it does not create an unlimited amount of nuclear energy; fuel rods still must be replaced after some time. Rather, the difference between this type of reactor and other types that account for the challenge is that breeder reactors reprocess the waste product of the fission reaction (plutonium) into fuel that other reactors cannot use. The reactor is able to generate more plutonium than more traditional reactors because it uses metal sodium as a coolant.

Metal sodium has a higher melting point than water (208°F compared to 32°F). One of the benefits of this process is that metal sodium does not slow neutrons down as much as water, making more neutrons available for the U-238 at the capture point, and thus forming more plutonium.³⁵

In order to separate the useable nuclear fuel from the waste, the spent fuel is chopped and dissolved through an acid bath process.³⁶ Uranium and plutonium are recovered and the remaining material is neutralized. This portion of the "fuel cycle process" is very expensive, requiring a great deal of safety measures given the the highly radioactive nature of some of the materials.³⁷

³⁴ Second Law of Thermodynamics.

³⁵ Carbon, *supra* note 18, at 78-79.

³⁶ PETER BECK, PROSPECTS AND STRATEGIES FOR NUCLEAR POWER: GLOBAL BOON OR DANGEROUS DIVERSION? (Earthscan, 1994)

12.

³⁷ *Id.*

In the 1940s, some predicted that the first reactors would be liquid metal reactors. The U.S. Navy developed water-cooled reactors with a great deal of success, and these systems were eventually adopted by the US nuclear industry. A number of other nations have also experimented with the technology – England, France, India, Japan, China, and Russia – but to little serious success, other than limited commercial use in Russia and Japan. The Ford and Carter administrations stopped US development of technology, but the Bush Administration has interest in it.³⁸

The benefits of this process are clear.³⁹ It lowers the cost of producing nuclear energy and somewhat limits the waste product of the reaction. One of the drawbacks of this technology is that the fuel rods must be discharged periodically and chemically reprocessed. A major problem with this detail, as noted by the Ford, Carter, and Clinton administrations, is that the breeder reactor creates a pure form of plutonium which can be harnessed for a weapon.⁴⁰

³⁸ The Ford and Carter Administrations hoped to send a message to the rest of the world by rejecting the process, hoping others would follow suit. See also Henry Sokolski, *Taking Proliferation Seriously*, POLICY REVIEW, at 51, Oct. 1, 2003 (describing the Bush administration's efforts to encourage breeder reactors in other nations and the administration's consideration of repealing the ban on reprocessing within the US).

³⁹ See A. David Rossin, *U.S. Policy on Spent Fuel Reprocessing*, Frontline, (1998), available at <http://www.pbs.org/wgbh/pages/frontline/shows/reaction/readings/rossin.html> (last visited Nov. 30, 2004) (advocating the benefits of reprocessing). See also Spurgeon M. Kenney, Jr., *Plutonium Reprocessing: Twenty Years Experience (1977-1997)*, FRONTLINE, (1998), available at <http://www.pbs.org/wgbh/pages/frontline/shows/reaction/readings/keeney.html> (last visited Nov. 30, 2004).

⁴⁰ Carbon, *supra* note 18, at 80.

4. Integral Fast Reactors

One recent development in the technology, known as the Integral Fast Reactor (“IFR”), uses a different form of chemical processing and different form of fuel rod.⁴¹ The process never creates pure plutonium – instead, it utilizes mixed fragments within the fuel cycle process, both fission materials and transuranic elements, making diversion very difficult. In the event the material is stolen, a bomb could not be made without further chemical separation.⁴²

5. Thorium Reactors

Another relatively recent technology is the Radkowsky Thorium Reactor, which uses thorium in the fuel rods, in combination with other fissionable pre-made material, to create a theoretically diversion proof reactor.⁴³ The main limitation with thorium reactors has been that the process of using thorium is costly and requires the use of pre-made fissionable material (which often *could* be reprocessed). The Radkowsky reactor addresses this problem by separating the U-235 from the thorium into separate processes, thus dividing the component into one which creates neutrons for energy and fuel management.⁴⁴

⁴¹ See FRONTLINE, *Interview with Dr. Charles Till*, available at

<http://www.pbs.org/wgbh/pages/frontline/shows/reaction/interviews/till.html> (last visited Nov. 30, 2004) (discussing IFR technologies and the political decision that ended the research program).

⁴² *Id.* at 80. A demonstration reactor, using this technology, was developed and tested in Idaho in 1995, but the Clinton administration discontinued the program. Carbon, *supra* note 18, at 80.

⁴³ See Paul R. Kasten, SCIENCE AND GLOBAL SECURITY (Overseas Publishing Association, 1998) 237-269, available at http://www.princeton.edu/~globsec/publications/pdf/7_3kasten.pdf (discussing the technology and its feasibility).

⁴⁴ Seth Grae, *The Nuclear Non-Proliferation Treaty's Obligation to Transfer Peaceful Nuclear Technology: One Proposal of a Technology*, 19 FORDHAM INT'L L.J. 1985, 1994 (1996).

B. How can this process be used to develop nuclear weapons?

1. Fuel Rod Theft and Reprocessing

The uranium used in fuel rods cannot be used to make a bomb. The U-235 content in “enriched uranium” is around four or five percent; a mixture of U-235 and U-238 would, at least, have to be twenty percent U-235 to be explosive.⁴⁵ Similarly, the plutonium that might be in fuel rods would also be difficult to transform into a bomb. There is no plutonium in fresh fuel rods, so terrorists would have to steal spent fuel. The spent fuel itself is stored in casks and usually surrounded with security. Even if one could obtain a used fuel rod, it is extremely difficult to separate plutonium into a pure form needed to make a bomb. Such a process requires a means of shielding oneself from a high degree of radiation and the technology and knowledge to separate the material.⁴⁶ Additionally, the fuel rods within commercial reactors are used for three or four years at a time, due to their high cost; this leads to many impurities, making it difficult to develop the material into a weapon.⁴⁷

The more pertinent threat at the moment comes from advanced nuclear reactors that create a type of plutonium, through reprocessing that is more useful in weapon-making. In certain Soviet-style reactors, like the graphite-water reactor used in Chernobyl, the tendency was to replace the fuel much more frequently than normal reactors, as these reactors could generate a relatively large amount of plutonium, for

⁴⁵ Carbon, *supra* note 18, at 63.

⁴⁶ *Id.* at 64-65.

⁴⁷ Carbon, *supra* note 18, at 65.

weapons, while providing energy.⁴⁸ The sole purpose of traditional reprocessing plants is to separate plutonium and uranium from the used fuel, so those materials can be re-used: this means that a nation that can obtain a reprocessing facility has the capability of creating a great deal of plutonium in a short time.⁴⁹

2. Alternative Diffusion

Another facet of nuclear technology is that commercial reactors are not a likely candidate for plutonium processing. For example, plutonium can be processed in a more covert non-commercial reactor. In North Korea, this has usually been the issue – rather than develop nuclear reactors for energy purposes, the regime tends to favor more covert military development.⁵⁰ The majority of news coverage involving nuclear proliferation centers on these issues, as a nation state clearly has much more ability in terms of financing and organization to develop such materials into a weapon. These nations tend to focus on obtaining dual use technology, attempting to mask their military efforts for civil operations.

3. Waste

Finally, a fear that developed in the popular media after 9/11 was that terrorists could somehow obtain other nuclear waste material for use in a “dirty bomb” that would utilize the radiological effects of the nuclear material. There is no single definition of a dirty bomb – generally, the term refers to terrorists using nuclear material in a crude, non-conventional form, such as designing a method to expose a civilian to radiation without

⁴⁸ Garwin and Charpak, *supra* note 22, at 315.

⁴⁹ PETER BECK, PROSPECTS AND STRATEGIES FOR NUCLEAR POWER: GLOBAL BOON OR DANGEROUS DIVERSION? (Earthscan, 1994)

12.

⁵⁰ *Id.* at 69.

utilizing an active fissile reaction. The problem with analyzing the threat from a dirty bomb is that there is not a simple means of using the material as a weapon.

Most of the scenarios contemplated by security analysts deal with hypotheticals that have not yet happened. Some studies have calculated little risk to such accidents.⁵¹ There are other real life stories that nuclear material has led to some alarming results.⁵² Whatever the risk, after 9/11, the world is much more cognizant of the risks posed by terrorism.

IV. US Policy Actions in Response to the Threat of Reprocessing and Proliferation

The US has developed a number of policies aimed at curbing the threats of proliferation. They range from technological solutions to diplomatic solutions. While the US has had some success in the area of curbing proliferation, it appears there is much more that could be done to address the issue.

A. “Cooperative Threat Reduction” (“CTR”)

A result of the efforts of US Senator Richard Lugar and former Senator Sam Nunn, the “Nunn-Lugar” program, otherwise known as Cooperative Threat Reduction, attempts to address the uses of loose nuclear weapon materials in Russia and other nations. The fear is that Russian nuclear weapon or reactor components could be bought from, or stolen from, Russian facilities, given their lax security measure. Continuing the

⁵¹ See BERNARD L. COHEN, *THE NUCLEAR ENERGY OPTION: AN ALTERNATIVE FOR THE 90S* (1990), 221 (discussing a Sandia National Laboratory Study in which an experiment showed that exploding a truck filled with nuclear waste in Manhattan would have a twenty percent risk of killing *one* person).

⁵² *Id.* at 22-223 (describing the Kyshtym incident, in which misuse of radioactive waste created a dangerous chemical explosion in the former Soviet Union around 1957-1958).

consistent theme of this issue's complexity, the task of dismantling these weapons has proven very difficult.⁵³

1. Policy

While plutonium reprocessing is a much publicized portion of the CTR program, the program is much bigger. It has four broad goals: (1) Destroying nuclear, chemical, and other weapons of mass destruction; (2) transportation and safe storage of these weapons and materials; (3) establishing verifiable safeguards with regard to these weapons and material; and, (4) preventing the diversion of scientific expertise regarding nuclear technology.⁵⁴

2. Technical Process

Generally, there are two major nuclear-related processes to the CTR program. One program buys the enriched uranium from Russian weapons, re-processing it into nuclear fuel. The problem with this process is that it costs substantially more to produce MOX fuel for sale than it does to buy the more conventional uranium fuel. To encourage the use of MOX, the US plans to sell the materials at a price equal to or less than the uranium fuel that is normally used by domestic reactors.⁵⁵

Another process deals with the plutonium from Russian weapons. Generally, two methods are used to address this issue. Some plutonium is re-processed into fuel within commercial reactors while the rest is treated in a process known as "vitrification," in

⁵³ Each ton of plutonium is enough to make 200 nuclear weapons, and a ton of highly enriched uranium is enough for 50 nuclear weapons. The amount of plutonium that Russia would provide would be in the neighborhood of 10,000 plutonium weapons and 60,000 uranium weapons. Garwin and Charpak, *supra* note 22, at 329.

⁵⁴ Sharon Squassoni, *Globalizing Cooperative Threat Reduction: A Survey of Options*, CONGRESSIONAL RESEARCH SERVICE (Apr. 15, 2004), available at <http://fpc.state.gov/documents/organization/32006.pdf>.

⁵⁵ *Id.*

which the material is dissolved within glass. This glass material can be stored in a secure, neutralizing the threat posed by the material.

3. DOE, DOD, and DOS participation

The DOE is primarily responsible for the technical processes involved with CTR. The Department of Defense (DOD) shares some responsibility on these technical issues, but appears to be more of an executive after changes were made to the CTR program during the Bush administration: the Defense Threat Reduction Agency (DTRA), part of the DOD, is primarily responsible for the CTR program.⁵⁶ The State Department (DOS) is responsible for the diplomatic aspect of the program.

4. Implementation (and Difficulties)

The policy's implementation was slow. The Department of Defense (DOD) initially had a great deal of discretion with the program's funds, with the majority of the funding going towards security measures for the transportation and storage of nuclear weapons in the United States: Armed Service Procurement Regulations prevented the use of funding in the former Soviet Union.⁵⁷ After it became apparent that there were no incentives in place for Russian nuclear technicians to act in the best interests of Russia and the U.S., the DOE initiated a program between weapon laboratories in the two nations.

There have been other failures in the years since the program's inception. The Bush Administration has not always been interested in funding the initiative. Prior to 9/11, the Bush Administration tried to cut funding; even with the War on Terrorism, the

⁵⁶ DTRA, *DTRA Fact Sheet*, available at http://www.dtra.mil/press_resources/fact_sheets/display.cfm?fs=ctr (last updated December 2004).

⁵⁷ *Id.* at 325

Bush Administration has, at times, sought to divert funds for the initiative to other programs.⁵⁸ Finally, one of the great limitations of the program is that it does not address the limitations of nuclear facilities in other nations with any great magnitude. For example, the CTR program does not address the problems with nuclear reactors in nations such as Congo, Uzbekistan, and Ghana.⁵⁹

C. *The Nuclear Non-Proliferation Treaty (NPT)*

Under the Nuclear Non-Proliferation Treaty,⁶⁰ member states agreed to prevent the proliferation of nuclear weapons. It is largely a mixture of commitments regarding the oversight of member states (programs which have been in existence since the 1960s) and more bold commitments (like the quixotic agreement that all members will eventually disarm their nuclear weapons in Article VI).

Also, the International Atomic Energy Agency (“IAEA”) is enabled to inspect the commercial power activities of member nations. The treaty underscores the relationship

⁵⁸ Part of the delay was the result of a diplomatic dispute between Russian and US authorities over a number of issues, notably the certification of compliance. Richard Lugar, *Cooperative Threat Reduction*, available at <http://lugar.senate.gov/nunnlugar.html> (last visited Dec. 1, 2004).

⁵⁹ Michael Crowley, *Old Guard: W. Forgets the Nuclear Threat*, THE NEW REPUBLIC, Sept. 9, 2002. In Congo, the Kinshasa reactor is protected by a padlocked metal gate and has been missing a fuel rod since the 1980s. For a time after the 1997 coup in Congo, the IAEA was unable to inspect the plant. *Id.*

⁶⁰ Treaty for the Non-Proliferation of Nuclear Weapons, *entered into force*, March 5, 1970, 21 U.S.T. 483, 729 U.N.T.S. 161, available at <http://www.state.gov/t/np/trty/16281.htm#treaty>. [Hereinafter NPT.] The NPT is up for review next spring. Steve Andreasen, *Bush Must Strengthen Nuclear Weapons Treaty*, Boston Globe, Nov. 20, 2004, available at http://www.boston.com/news/globe/editorial_opinion/oped/articles/2004/11/20/bush_must_strengthen_nuclear_weapons_treaty?mode=PF. See also Press Release, State Dep’t, *U.S. Cites Response to NPT Noncompliance As Greatest Challenge - Seeks to define “central obligation” of the NPT* (May 10, 2004), available at 2004 WL 59152186 (discussing US view of central obligation of NPT, preventing the proliferation of nuclear weapons).

between commercial nuclear power and the security risks posed by nuclear technology. Another unique function of the NPT is the requirement that all member nations be willing to share nuclear energy technology.⁶¹

This treaty illustrates an interesting worldview of the 1960s. The US and USSR were concerned with winning over less developed nations that were in need of energy. These nations were limited, due to a lack of natural resources and their large populations, in their ability to develop infrastructure and acquire technology. The US and USSR were more than willing to provide development assistance, taking on such projects as the Aswan High Dam in Egypt and the projects and assistance provided by the World Bank. Nuclear energy was another bargaining chip in the efforts to obtain allies, with the US reactors supplying assistance to nations like Congo, and the Cold War powers' willingness to sign a treaty guaranteeing that interest.

What happened to this enthusiasm for developing nuclear energy technology? The most obvious answer is that the Cold War ended, and, to a large degree, so did the US need to battle for the allegiance of those powers. For the US, the post-Cold War world was no longer bi-polar, but rather fraught with pariah states like Iran, North Korea, and Iraq, who would develop reactors for military purposes.⁶² This caused a shift from concerns over international goodwill to a concern over immediate security threats. Secondary causes were the loss of interest in nuclear energy in the US, with fears of accidents after Chernobyl, the media coverage of Three Mile Island, and the perceived risks of nuclear energy following 9/11.

⁶¹ NPT, *supra* note 43, Art. IV, sec 2

⁶² In North Korea, for example, it would seem the end of the Cold War increased the need for security, with the perceived fear of threats to the regime.

C. The International Atomic Energy Agency (IAEA)

The IAEA, based in Vienna, Austria, is a United Nations agency that came under fire in the months leading up to the 2002 invasion of Iraq. The IAEA has three general functions: promoting safeguards and verification, promoting safety and security, and promoting science and technology.

In terms of promoting safeguards and verifications, the IAEA has two broad functions. It inspects the nuclear-related facilities of member states and, under the auspices of UN Security Council resolutions, has maintained a presence in Iraq to monitor nuclear-related events there (although that function no longer exists).⁶³

With regard to the safety and security function, the IAEA oversees that member states have safe nuclear equipment: generally, the IAEA sets safety standards for nuclear facilities.⁶⁴ In the security area, the IAEA attempts to ensure that nuclear materials within member states are kept out of the hands of terrorists and those who might obtain the technology for military applications.⁶⁵

The IAEA, following the philosophy of the NPT, is also mobilized to promote science and technology: the IAEA maintains, as part of its mission statement, that it will promote exchanges of knowledge regarding nuclear technology towards developing nations (for energy and social benefits) and promote the research and development of

⁶³ IAEA, "Our Work: Safeguards and Verification," available at <http://www.iaea.org/OurWork/SV/index.html> (last visited Nov. 29, 2004).

⁶⁴ IAEA, "Our Work: Safety and Security," available at <http://www.iaea.org/OurWork/SS/index.html> (last visited Nov. 29, 2004),

⁶⁵ *Id.*

technology related to corresponding nuclear technology issues (food, safety, and radiation exposure).⁶⁶

The IAEA is severely limited in its amount of funding – its \$100 million budget is on par with that of a midsize American city.⁶⁷ Moreover, the budget has seen no real growth in seventeen years, even as the IAEA’s mission would seemingly be more important in a post-Cold War world.⁶⁸ The IAEA’s image took some damage during the buildup to the 2003 invasion of Iraq, as the Bush Administration’s public relations teams mocked Hans Blix and international inspection methods used within Iraq.

D. Diversion-proof fuel

A relatively recent proposal would focus on a method that would make nuclear power plant spent fuel useless for weapon purposes. By putting an isotope of americium, Am-241, in all new fuel rods, neutrons can be captured while the rods are in the reactor. A curium isotope, Cm-242, would be created, and, in turn, this material would eventually deteriorate into Pu-238. If this process is timed appropriately, the theory is that it would render spent fuel from weapons useless.⁶⁹

There are two policy concerns related to such a solution. First of all, it would be necessary to create a treaty system in which fuel fabrication systems were open to inspection. Second, and a reality that advocates of such a system are quick to point out,

⁶⁶ IAEA, Our “Work: Promoting Science and Technology,” available at <http://www.iaea.org/OurWork/ST/index.html> (last accessed Nov. 29, 2004).

⁶⁷ Michael Crowley, *Old Guard: W. Forgets the Nuclear Threat*, THE NEW REPUBLIC, at 15 (Sept. 9, 2002).

⁶⁸ *Id.*

⁶⁹ Carbon, *supra note 17*, at 70

is that there are very few fuel fabrication plants in the world, making the inspection easy to control.⁷⁰

E. Export Controls

The DOE has oversight of the export of nuclear technology, including nuclear reactors.⁷¹ Failure to comply with the export controls carries stiff penalties, such as jail time and fines.

F. Direct Foreign Policy Measures

The actions of the US through international negotiations and other foreign policy acts must be mentioned in any discussion of proliferation. In the past, the US has used a variety of different strategies, depending on the situation. In the case of Brazil and Argentina, the US joined members of the international community to negotiate a series of agreements in which the two nations would join the NPT and agree to mutual verification measures.⁷² In 1994, North Korea and the US agreed to shut down of a North Korean reprocessing plant in exchange for two light water reactors less suited for weapon making.⁷³ Of course, since that time, the US has used a less conciliatory method with North Korea, instead choosing to implicitly threaten military action. A more “hard line” approach is that taken by the US with regard to Iraq’s efforts to develop nuclear technology.

⁷⁰ *Id.*

⁷¹ Atomic Energy Act, 68 STAT. 919 (1954). The specific regulations are governed by DOE regulations. 10 C.F.R. § 810 (1995).

⁷² Recent developments deserves special attention as Brazil recently received authorization from the IAEA to enrich uranium Raymond Colitt , *Brazil in deal with nuclear watchdog*, FINANCIAL TIMES,, Nov. 26, 2004 available at 2004 WL 100695398.

⁷³ ENERGY, *Forget Atoms for Peace*, Sept. 22, 2000, at 2

V. Analysis

The following is a brief commentary of several major emerging issues related to nuclear energy, using the information presented above.

1) Should the United States promote the use of nuclear energy?

This issue turns on the extent to which one believes there is a technologically feasible solution to the reprocessing problem within nuclear technology. The Ford and Carter Administrations concluded that there was no such solution and that the risks of plutonium proliferation outweighed the benefit of the technology and thus, arguably, dealt a serious blow to the research and development aspects of nuclear technology, in turn contributing to the change in US policy regarding the promotion of the technology worldwide. It would be interesting to know the feeling of those administrations regarding reprocessing technology like IFRs in making such decisions.

The benefits of nuclear energy are clear. It can provide relatively cheap and emission-free energy in places that lack sufficient natural resources to provide for their population. As international energy demand continues to rise, nuclear energy is a clear answer to offset the corresponding rise in cost.

Furthermore, the promotion of such technology, if safe, while not serving an ideological interest like it did during the Cold War, could serve a more prophylactic measure in the future. Some of the most frightening nations in the world – North Korea, Belarus, and Afghanistan – are also extremely limited in their energy infrastructure. Even if they could grow, these nations often lack the capability to develop the basic services, like sufficient electric access, needed for successful development. Energy

access could serve as preventive measure to the social problems that come with a poor economy and contribute to the malaise that enables a regime like the one in North Korea. While hardly a guaranteed solution, it seems that nuclear energy could offset those problems. Proliferation safe reactors, whether they be IFRs, thorium reactors, or simple light water reactors (which often make the cost of reprocessing too great), would offset some of these concerns. Better international monitoring could also contribute a great deal to the proliferation concern.

2) *What measures can be taken to ameliorate the proliferation risks posed by nuclear energy?*

Proliferation safe reactors, whether they be IFRs or simple light water reactors (which often make the cost of reprocessing too great), would offset proliferation concerns. US policymakers should at least evaluate the possibilities of these technologies, rather than relegate them to the present status as Cold War relics.

Better international monitoring could also contribute a great deal to the proliferation concern. At present, the IAEA is woefully under-funded, given its magnificent responsibility of overseeing the safety of nuclear technology around the world. Changes to the organization, whether through an increase in funding or a reassignment of the task to another organization, are necessary.

Finally, the US must choose whether it intends to enforce the NPT, an international agreement that sought to limit the military applications of nuclear technology. The US has, at times, failed to live up to other obligations of the agreement such as the nuclear Test Ban Treaty (CTBT). If the US wants to seriously pursue the

concerns of nuclear proliferation, it ought to comply with the NPT and encourage other nations to follow suit.

3) Is the present division of labor appropriate within the federal government appropriate to address the myriad of issues created by the unique nature of nuclear technology?

Given the analysis presented above, there should be little doubt that the federal government's oversight of nuclear issues should be re-thought, particularly in the realm of nuclear proliferation. The US has failed in implementing a clear strategy to prevent future abuses of nuclear technology.

One idea, following 9/11, is to create a separate White House post, overseeing the myriad of DOE, DOD, and DOS programs related to the international trade of nuclear materials.⁷⁴ This "nuclear proliferation czar" would be designed to coordinate the respective efforts of the various foreign and domestic policymaking bodies involved with proliferation issues, with the overall goal of developing a unified policy.

The Bush Administration has also proclaimed a "Global Threat Reduction Initiative," which would expand the Nunn-Lugar program. The program would compensate for the external limitations of the existing CTR program, expanding the DOE's anti-proliferation efforts beyond Russia. The success of this program remains to be seen.⁷⁵

⁷⁴ *Id.*

⁷⁵ D.O.E., *Global Threat Reduction Initiative Highlights*,

http://www.energy.gov/engine/doe/files/dynamic/264200491138_Vienna_GTR_Fact%20Sheet_FINAL1_052604%20.pdf (discussing the Bush Administration Global Threat Reduction Initiative), *last visited* Dec. 1, 2004. *See also* Sharon Squasanni, *Globalizing Cooperative Threat Reduction*, CONGRESSIONAL RESEARCH SERVICE (Apr. 15, 2004) (*available at* <http://fpc.state.gov/documents/organization/32006.pdf>) (describing specific measures to expand CTR programs).

In line with the issue of coordination, the US, if it chooses to promote nuclear energy, ought to be a leader in developing safer civilian applications of the technology, promoting the use of technology like integral fast reactors, thorium reactors, and diversion proof fuel. Some have argued that sharing this technology is an obligation under the NPT.⁷⁶

VI. Conclusion: Two Broad Observations on Nuclear Energy and Nuclear Proliferation

This analysis also warrants two additional observations on nuclear energy worth noting. First, one of the more striking aspects of the last two decades is the lack of legitimate research and development into nuclear energy. The US has always been a world leader in technological development and, not surprisingly, research and development into nuclear energy began to slow around the time that the US ended its research. In the US, following the decision to ban reprocessing, there was some experimentation with IFRs, but even that research has been dormant for over a decade. As the development has subsided, so too has the US interest in nuclear energy, given the prospect of more decommissioning of plants on the horizon without an offsetting increase in the number of plant applications. There have been no new ideas and thus no new policies. If the argument that nuclear energy is a necessary step to offset the increased international demand is correct, then any policy that does not take those technological development issues into account is a mistake.

Second, the problems related to nuclear energy and proliferation will not go away under the current policy framework. Foreign nations will still need energy and, occasionally, a state will attempt to increase its hegemony through the development of

⁷⁶ Seth Grae, *The Nuclear Non-Proliferation Treaty's Obligation to Transfer Peaceful Nuclear Technology: One Proposal of a Technology*, 19 *FORDHAM INT'L L.J.* 1985, 1998 (1996).

nuclear weapons.⁷⁷ This reality demands vigilance regarding the problems of proliferation. One commentator, ranking nuclear proliferation as the most serious risk associated with nuclear energy, explained a method for evaluating the risk associated with nuclear proliferation:

[The] risk, in the formal sense, is the product of the probability of a harmful event times the consequences of the event if it takes place. Now, we do not know exactly how much the spread of nuclear power contributes to the probability of nuclear war, but it is certainly not inconceivable that the probability of nuclear war is already [one percent] per year and that the spread of nuclear power could double that figure in the short term . . . If nuclear power adds a probability of [one percent] per year to the chances of nuclear war, and recognizing that the consequences of nuclear war could include the deaths . . . of billions of people, then the “expected value” associated with that risk – that is, the probability times the consequences – is very large indeed.⁷⁸

There is no clear way to evaluate the risk of a nuclear accident, much less the risk posed by nuclear proliferation. The lack of a tangible means of evaluating the probability of such incidents is not a reason to ignore the problem. If nuclear energy is a necessary step in addressing the rising energy demand worldwide, it will take an investment in the future to protect the world from dangers posed by nuclear proliferation. Allowing examples like the Kinshasa reactor mentioned in the introduction to discourage a policy that pursues the safe development of nuclear energy is a mistake.

⁷⁷ Recently, Iran again made the news with allegations from the US State department over their use of nuclear technology. The IAEA stepped in and felt comfortable with the result of its oversight. The Bush administration soon responded with allegations that the nuclear reactors in Iraq were being used for military purposes.

⁷⁸ JOHN P. HOLDREN, PERSPECTIVES ON ENERGY (Lon C. Ruedisili and Morris W. Firebaugh, ed. 1982), 374.